

4.2 CALIBRATION OF THE EVERGLADES AND THE LEC

The goal of the Everglades/LEC calibration effort was to make simulated stages at selected monitoring/observation points and canals, and simulated discharges through selected structures match historical data as reasonably close as possible. All historical input data, including structure flows, were assumed to be reliable. The question of data reliability will be addressed to some extent in Chap. 5. The model is calibrated on a regular basis to ensure that its history matching capability is maintained or improved after significant computer code changes have been made and/or data updates have been performed. It must be emphasized that calibration also enhances, but not guarantee, a model's predictive capability.

Methodology

A network of groundwater monitoring or observation wells is maintained by the District and the USGS. Observations from this network were used to make stage comparisons during calibration (Fig. 4.2.1). Although the simulation was performed on a daily basis, simulated water levels were compared with historical data on an end-of-week basis. Comparing historical data with simulated values on a daily basis was not justifiable because of several factors:

1. The spatial resolution of the model, 2 miles by 2 miles, is too coarse for modeling local phenomena such as wellfield drawdowns and levee seepage.
2. The time resolution of the model, 1 day, may not always satisfy certain assumptions in the model. For example, in the overland flow subroutine, in order to maintain stability in the solution procedure, volume constraints during some simulation days may override the assumption that overland flow is a diffusion type process.
3. The availability or lack of continuous flow and stage information preclude daily comparison of historical data and simulated values. Even if data is available, daily comparison is statistically noisier than weekly or monthly comparison.
4. The intended use of the model is to provide long-term planning-type guidance to water managers with regards to making water policy decisions. The model is not intended to estimate system responses to extreme conditions whose timing may be in the order of hours or even minutes (e.g. flood events). It is also not intended to be a prescriptive model that a field operator can use in making decisions on when and by how much to open a sluice gate, for instance, on a day-to-day basis.

Canal stages were also considered in the calibration. Due to the more dynamic nature of canal levels relative to groundwater levels, as well as the coarse representation of canals in the model (refer to Sec. 2.5), a comparison of average monthly stages was selected.

In general, the time series of historical flows, where available and considered reliable, were input to the model. Discharges at some locations with sparse and/or unreliable historical data were compared to simulated values on a monthly, seasonal and annual bases. Appendix F contains the full set of water level (ground water and surface water) calibration and verification/validation plots for the Everglades and the Lower East Coast areas. Appendix G shows the calibration and verification/validation plots for canal stages, and Appendix H compares SFWMM-simulated structure flows against historical values.

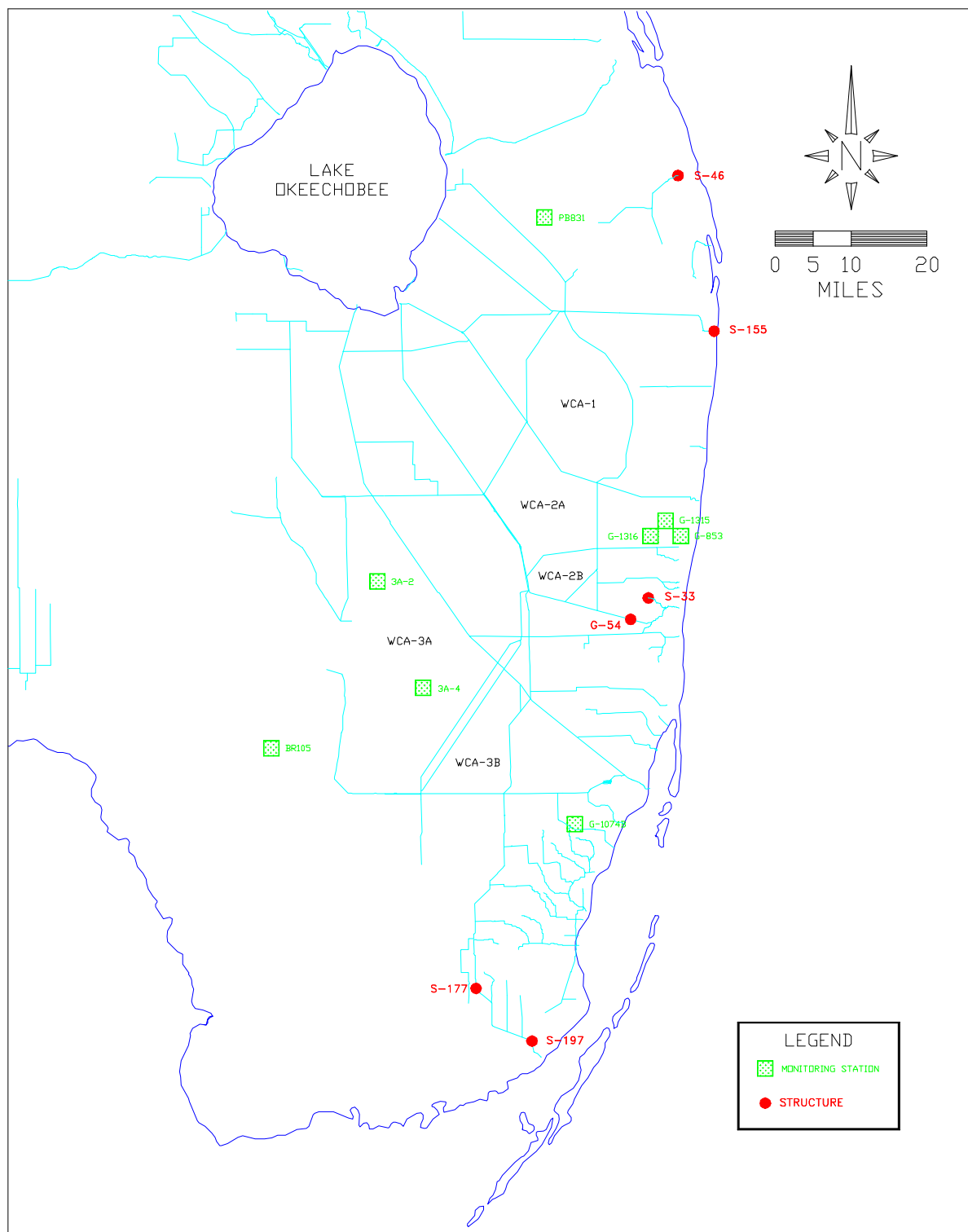


Figure 4.2.1 Location of Selected Groundwater Level Monitoring or Observation Wells Used in the South Florida Water Management Model Calibration

Calibration for the majority of the model domain (LEC, WCA, ENP, and BCNP) was performed in an iterative fashion: (1) simulated stages were compared with historical stages at selected monitoring points and simulated flows were compared with historical flows at control structures; (2) appropriate calibration parameters were modified in order to make simulated values match historical values more closely; (3) the model was rerun with the revised parameters; and (4) step (1) was repeated until an acceptable match between simulated and historical values was obtained.

The use of historical flows as boundary conditions at certain structures, instead of actually simulating the discharge through those structures during calibration, allowed physical processes to be calibrated without being affected by possible changes to operating practices. One of the strengths of the SFWMM is its ability to show the response of groundwater levels to water resources management. Historical flows, which are determined by structure hydraulics as well as structure operating rules, encapsulate field-level decision making processes, which may deviate from what is specified in operating manuals.

Several parameters can be adjusted to calibrate the Everglades and LEC portions of the model domain. A breakdown of the most significant parameters used in the calibration procedure is given below.

A. Lower East Coast

1. Canal parameters:
 - a. channel - aquifer hydraulic conductivity coefficient [CHHC in Eq. (2.4.1)];
 - b. surface water - channel interaction [n in Sec. 2.5];
 - c. coefficients for operation of outlet structures;
2. Detention depths (refer to Sec. 2.3); and
3. ET coefficients (KVEG, DSRZ, DDRZ in Sec. 2.2).

B. Everglades (WCAs, ENP and BCNP)

1. ET coefficients (KVEG, DSRZ, DDRZ in Sec. 2.2);
2. Manning's n ($n = Ah^b$ for overland flow; mainly A is adjusted);
3. Levee seepage rate coefficients [β_0 , β_1 , β_2 , in Eq. (2.4.2)];
4. Detention depths (refer to Sec. 2.3); and
5. Canal parameters (refer to Secs. 2.4 and 2.5).

The general guidelines used in calibrating the model were discussed in Chap. 4. Additional guidelines specific to the Everglades/LEC region are listed below.

1. The calibration period covered historical data consistent with a relatively static “plumbing” system and constant structure operating rules.
2. Local parameters such as canal properties and cell-based data, were adjusted before regional parameters were adjusted. Regional parameters such as land use type have greater areal influence. This procedure was followed to minimize the undesirable effect of the calibration getting better in some areas but negatively affecting other areas in the model domain.
3. Exact matching of historical data may not be desirable in some cells during the calibration process. The simulated stage represents the average water level computed for a 4-mile² area. Comparing historical stage, a point measurement, against simulated stage, an estimated areal average, is a source of discrepancy in itself. Some monitoring points are located near a

municipal wellfield which can heavily influence the stage at that location. Since the model cannot accurately simulate wellfield drawdowns at such a small scale, matching stages at that particular location becomes a futile effort. Good engineering judgement must be used.

4. It was shown (Trimble, 1995a) that canals heavily influence groundwater levels within its immediate proximity. The monitoring point closest to the canal, assuming that several observation points exist within the cell where the canal is located, gets priority for the stage matching.
5. In addition to comparing seasonal and annual sums and means, the following statistical measures and their corresponding ranges were used to evaluate the status of the calibration after each parameter change.

coefficient of determination or correlation coefficient, R^2 :

$$R^2 = \left[\frac{\sum_{i=1}^n (x_i - x_m) (\hat{x}_i - \hat{x}_m)}{\sqrt{\sum_{i=1}^n (x_i - x_m)^2 \sum_{i=1}^n (\hat{x}_i - \hat{x}_m)^2}} \right]^2 ; \quad 0 \leq R^2 \leq +1 \quad (4.2.1)$$

mean square error, **mse** :

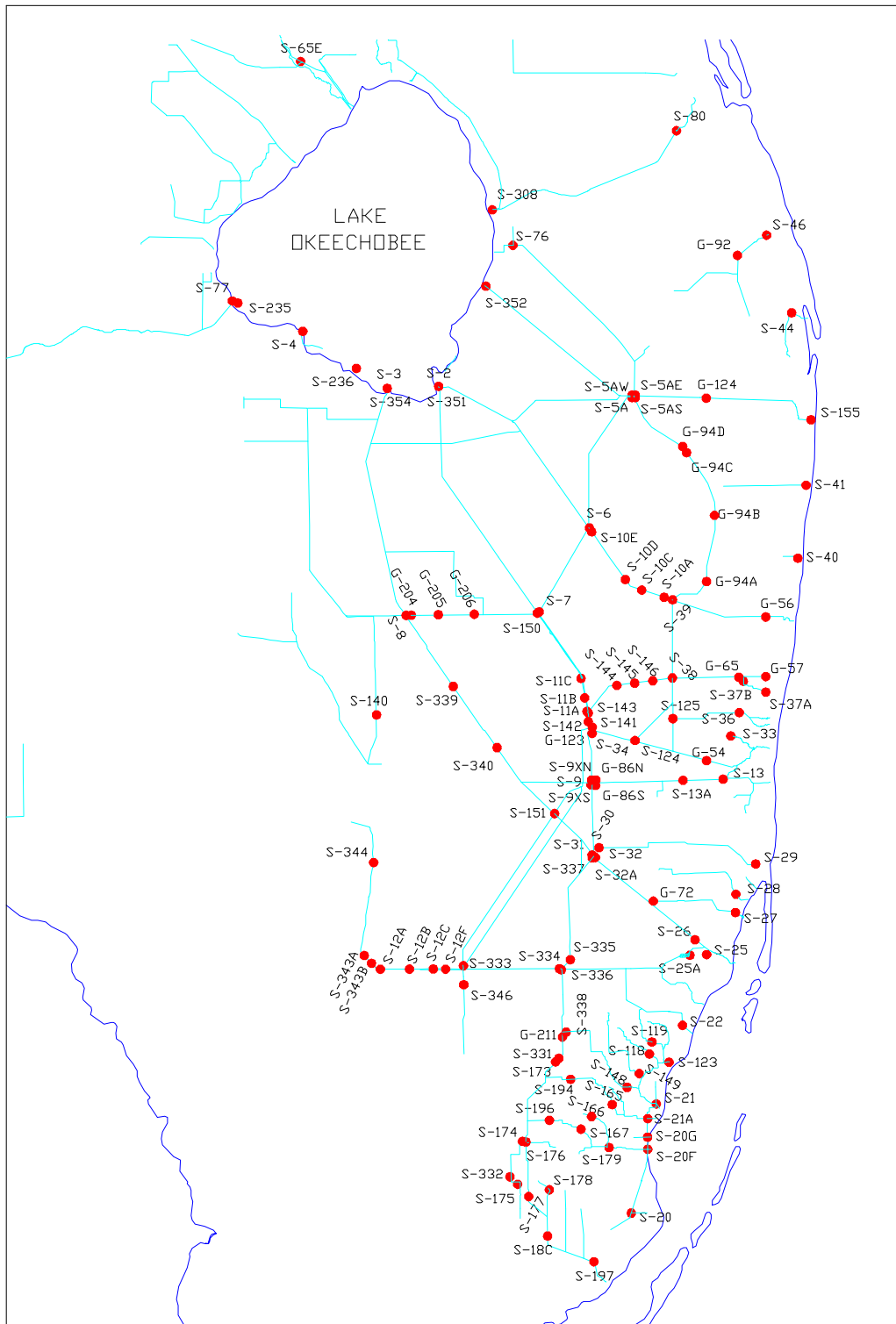
$$mse = \frac{\sum_{i=1}^n (\hat{x}_i - x_i)^2}{n-1} ; \quad 0 \leq mse \leq +\infty \quad (4.2.2)$$

bias:

$$bias = \frac{\sum_{i=1}^n (\hat{x}_i - x_i)}{n} ; \quad -\infty \leq bias \leq +\infty \quad (4.2.3)$$

where: n = number of data points;
 x_i = observed data point;
 x_m = mean of observed data points;
 \hat{x}_i = simulated data point; and
 \hat{x}_m = mean of simulated data points.

The selected calibration period includes calendar years 1979 through 1990 and verification / validation years from 1991 through 1995. Because the South Dade Conveyance System (SDCS) was completed in 1982, the calibration during the first three years of the selected period was relaxed for that region of the model domain. All comparisons using the above statistical measures were performed by limiting the number of data points by the size of available historical data. In other words, simulated data with no corresponding historical data were not considered in all statistical calculations.



Everglades and LEC Calibration Results

Calibration results for the Everglades (WCAs and portions of the ENP and the BCNP) and LEC Service Areas are presented next. The figures that follow show representative comparisons of end-of-week stages for various monitoring points and monthly average stages for several canals throughout the model domain. Comparisons of simulated and historical monthly and annual flow volumes are also included for selected structures. Figs. 4.2.1 and 4.2.2 can be used to locate the gages referenced in the following discussion. Appendices F and G contain the full set (161 monitoring points and 22 canal locations, respectively) of calibration and verification plots based on SFWMM v3.5.

The effect of wellfields on the system is illustrated in Figs. 4.2.3(a) and (b). G1074B (x,y: 31,20) is located within the cone of influence of the Alexander Orr, Jr. wellfield in Dade County, and G853 (x,y: 38,39) is situated in the same SFWMM grid cell where the Northeast wellfields of the city of Pompano Beach in Broward County are located. In both instances, the model is unable to track the wide fluctuations in groundwater levels at these two sites. This discrepancy could be reduced only if finer grid cells and/or finer time scales were used.

Another limitation of the model is related to one of the assumptions used to route water through canals: the water surface profile in a canal reach is assumed to have a constant slope, HDC (refer to Sec. 2.5). In Figs. 4.2.4(a) and (b), two gaging stations, G1315 (x,y: 37,40) and G1316 (x,y: 36,39), are located on opposite ends of one of the secondary canals maintained by the Deerfield Agricultural District just south of the Palm Beach-Broward county line. The model simulates stages in the upstream monitoring point (G1315) better than it does on the downstream end (G1316). Although the difficulty presented by these two gaging stations to the entire calibration effort do not occur frequently, suggested model improvements, in addition to better data collection, to offset it are: (1) include a time-varying HDC; or (2) revise the canal routing algorithm to be consistent with the more accurate distributed flow routing techniques.

The importance of regional parameters, such as ET parameters, which are functions of land use, is illustrated in Figs. 4.2.5(a) and (b). PB831 (x,y: 29,60), located in northwestern Palm Beach county, and BR105 (x,y: 11,25), located in southeastern Collier county within the Big Cypress National Park, are both located in grid cells with the same land use classification: forest. During dry periods, PB831 tends to overestimate stages while BR105 tends to underestimate stages. Since both monitoring points are located within the same type of "natural" areas, candidate parameters for calibration are limited to ET parameters. Adjusting such parameters will have conflicting effects at the two locations. A decision was made to emphasize stage matching for PB831 since it is closer to urban development where related water management issues have to be made. This example illustrates that some times subjectivity may be required in model calibration.

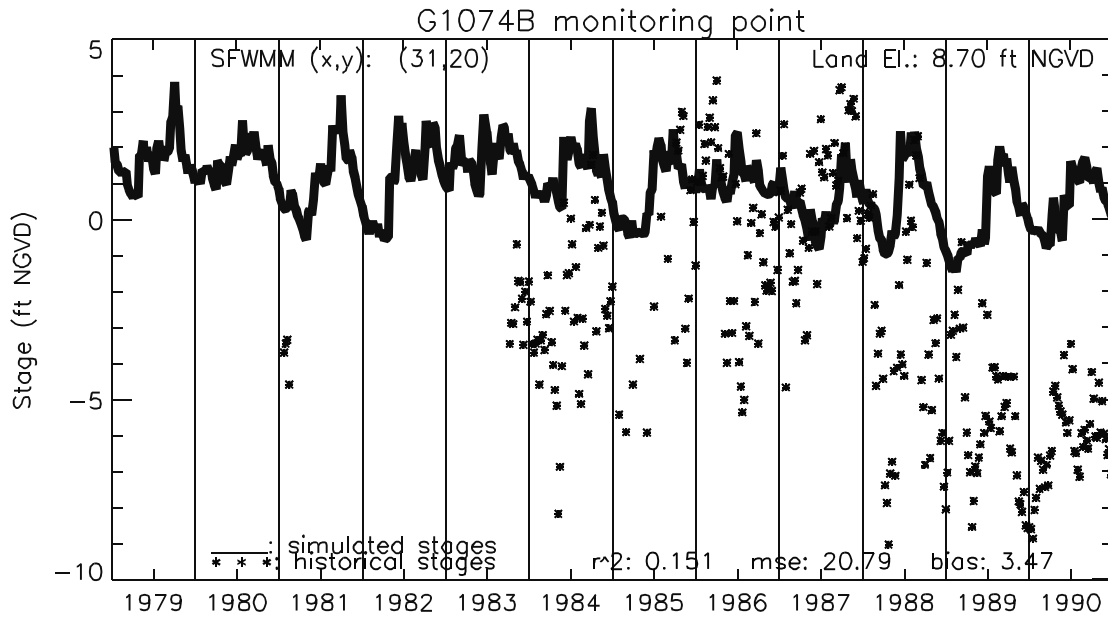


Figure 4.2.3(a) Comparison of Simulated and Historical End-of-Week Stages at Gage Location G1074B for Period of Record 1979-1990

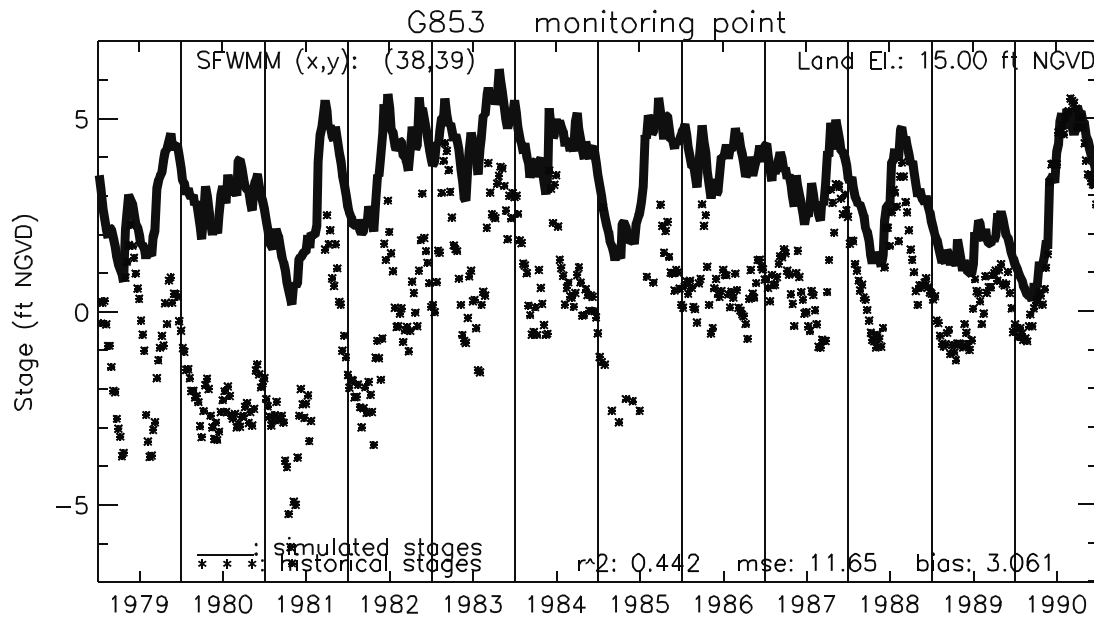


Figure 4.2.3(b) Comparison of Simulated and Historical End-of-Week Stages at Gage Location G853 for Period of Record 1979-1990

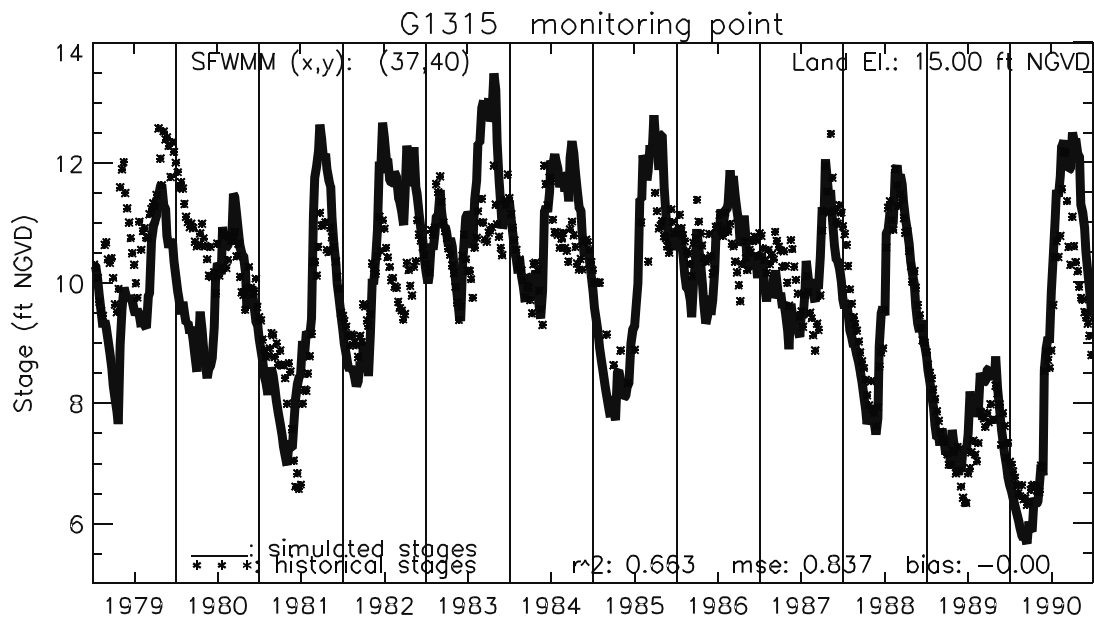


Figure 4.2.4(a) Comparison of Simulated and Historical End-of-Week Stages at Gage Location G1315 for Period of Record 1979-1990

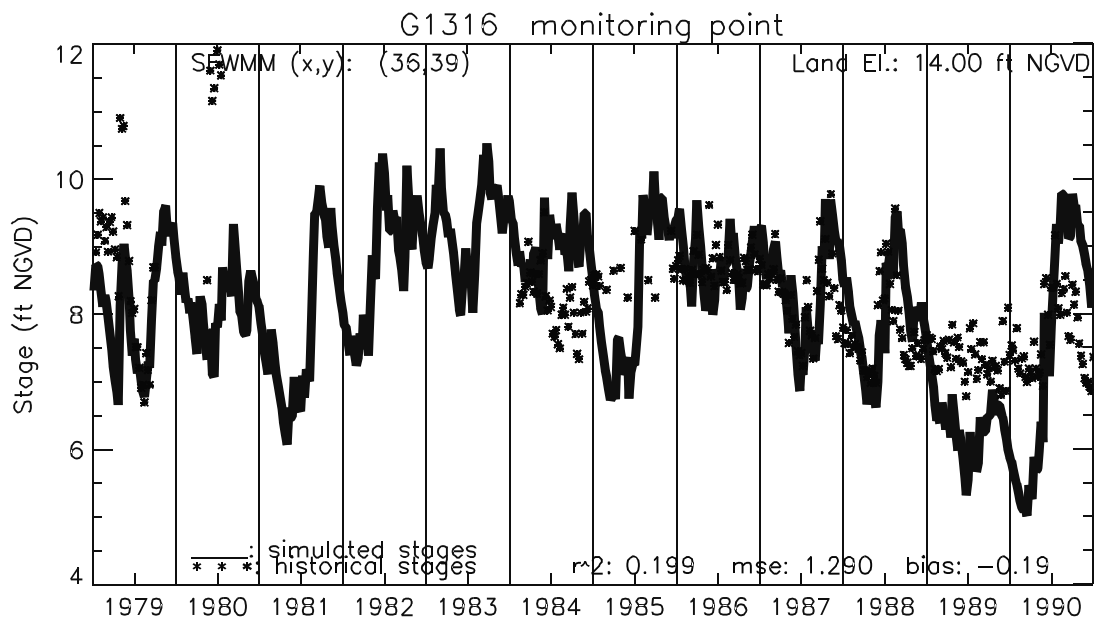


Figure 4.2.4(b) Comparison of Simulated and Historical End-of-Week Stages at Gage Location G1316 for Period of Record 1979-1990

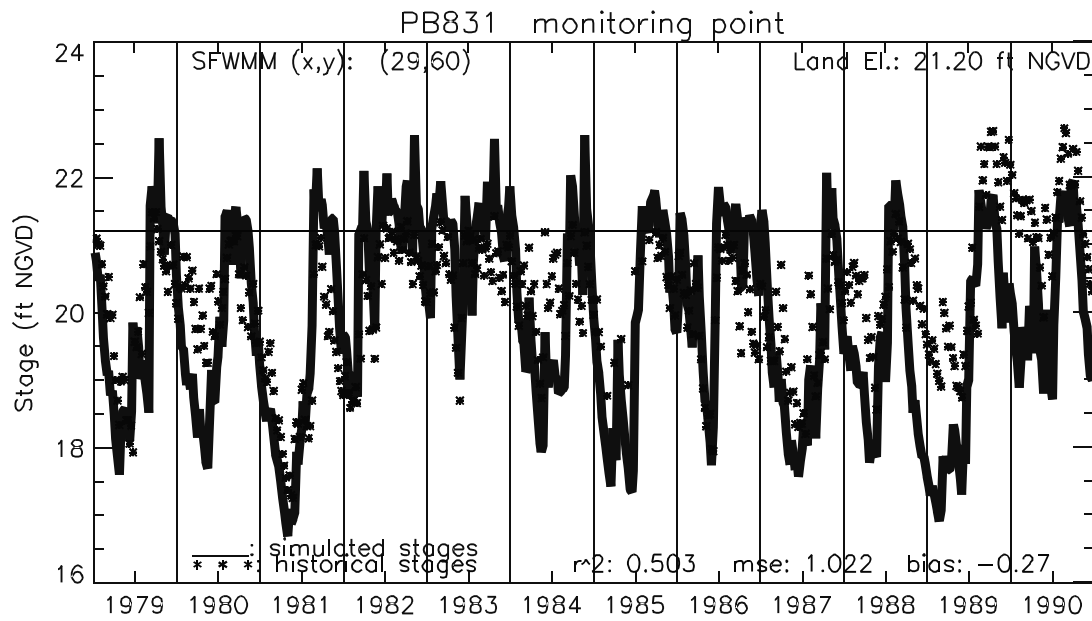


Figure 4.2.5(a) Comparison of Simulated and Historical End-of-Week Stages at Gage Location PB831 for Period of Record 1979-1990

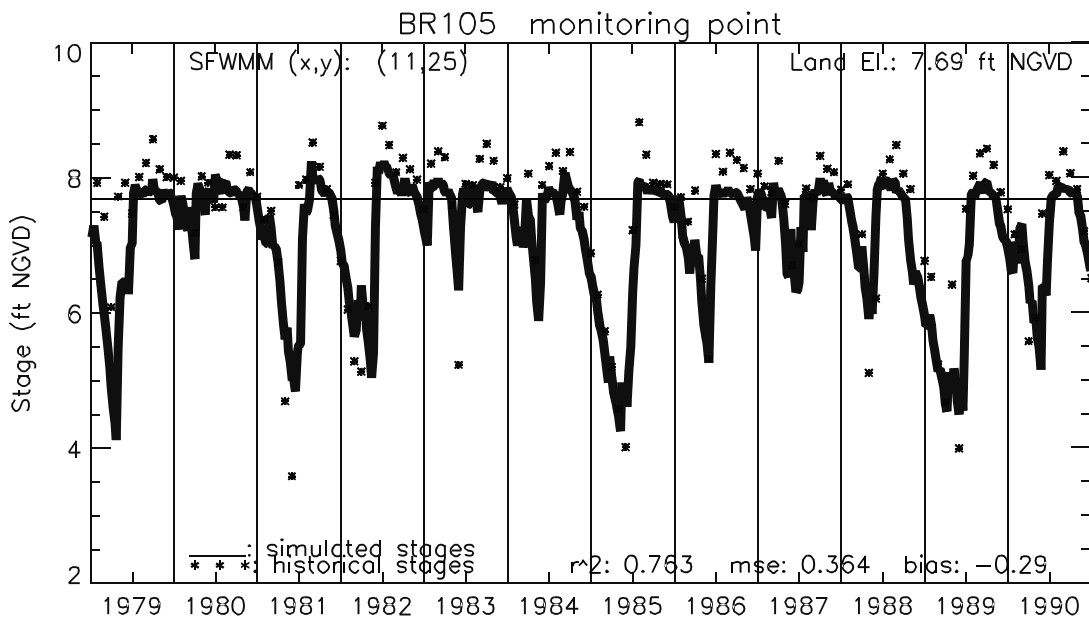


Figure 4.2.5(b) Comparison of Simulated and Historical End-of-Week Stages at Gage Location BR105 for Period of Record 1979-1990

Preferential stage matching in the model calibration may also be necessary in situations where a monitoring point is used to make operational decisions in the field. Gage 3A-4 (x,y: 21,29) is used as a basis for making regulatory discharges from WCA-3A. Additional effort was invested in improving the calibration at this location [Fig. 4.2.6(b)], in terms of minimizing overestimation of highs and underestimation of lows, as compared to 3A-2 (x,y: 18,36), a gaging station less than ten miles away [Fig. 4.2.6(a)] to the northwest of 3A-4. Both locations have the same vegetation type.

Historical values of canal stages measured at the headwater of the downstream structures (denoted by “Ref. Structure” in the calibration plots) are also compared to simulated stages during the calibration process. Figs. 4.2.7(a) and (b) are calibration plots for the upper C-103N canal and the North New River Canal (NNRC). The model performs a fairly good simulation of canal stages for C-103N canal but fails to trace wide fluctuations in NNRC stages. During wet periods the gates at G-54 are open full allowing the headwater stage to be quite low. During these times the slope of the water surface is relatively steep and nonlinear in geometry. Since the channel flow routing uses a mass balance approach and assumes a constant slope (linear) profile, the greatest error in the simulated stage along the North New River Canal would be at the downstream structure: G-54. The linearity assumption on the water surface slope becomes more valid further upstream.

As mentioned earlier, the selection of the calibration period (1979-1990) was largely dictated by the completion of the infrastructure associated with the South Dade Conveyance System in 1982. Figs. 4.2.8 and 4.2.10 show the calibration of stages and flow volumes at S-177, one of the major structures in the SDCS. More emphasis was made in matching historical stages and flow volumes after 1982. Historical stages and flow volumes for 1989 and 1990 deviate significantly from simulated values. This discrepancy may be due to operational policies instituted for SDCS during those two drought years.

Another operational change that might explain substantial deviations between historical and simulated stages can be illustrated in Fig. 4.2.9. Recorded low stages between 1982 and 1984 for the C-51 canal imply that the gates at its downstream structure, S-155, were opened earlier than usual, i.e., the actual canal maintenance level is lower during this two-year period. The model assumes fixed operational policies during a given simulation period and therefore, does not capture deviations from the "normal" maintenance level. On a positive note, Fig. 4.2.11 represents probably the best calibration information that the model can offer as far as matching historical flow volumes out of coastal structures. In general, flow volume trends on an annual, dry- and wet-season bases are sufficiently simulated by the model.

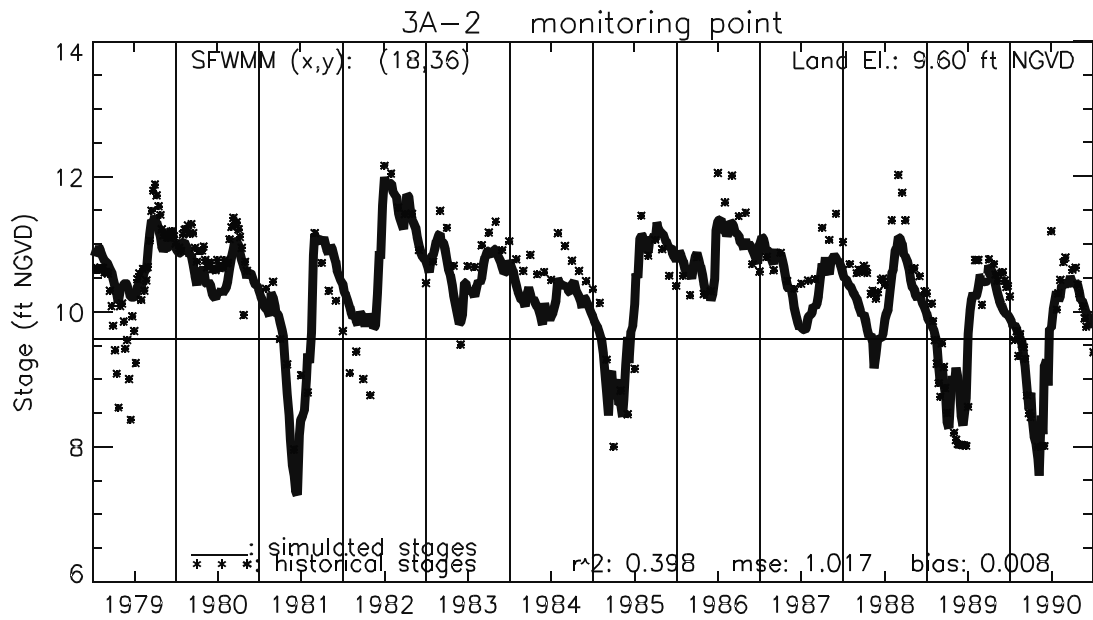


Figure 4.2.6(a) Comparison of Simulated and Historical End-of-Week Stages at Gage Location 3A-2 for Period of Record 1979-1990

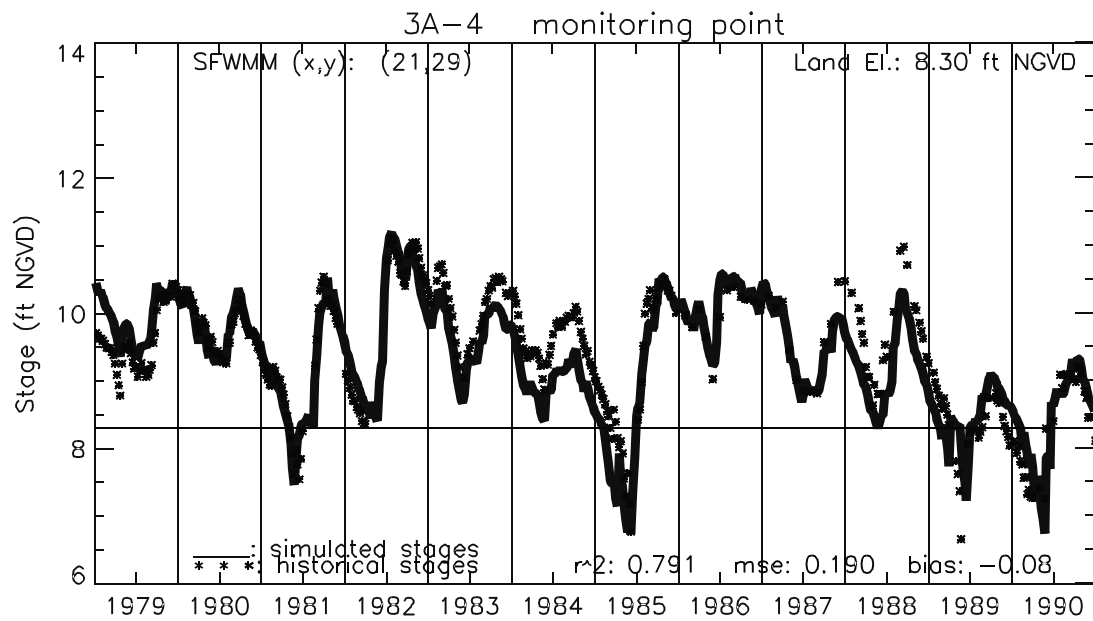


Figure 4.2.6(b) Comparison of Simulated and Historical End-of-Week Stages at Gage Location 3A-4 for Period of Record 1979-1990

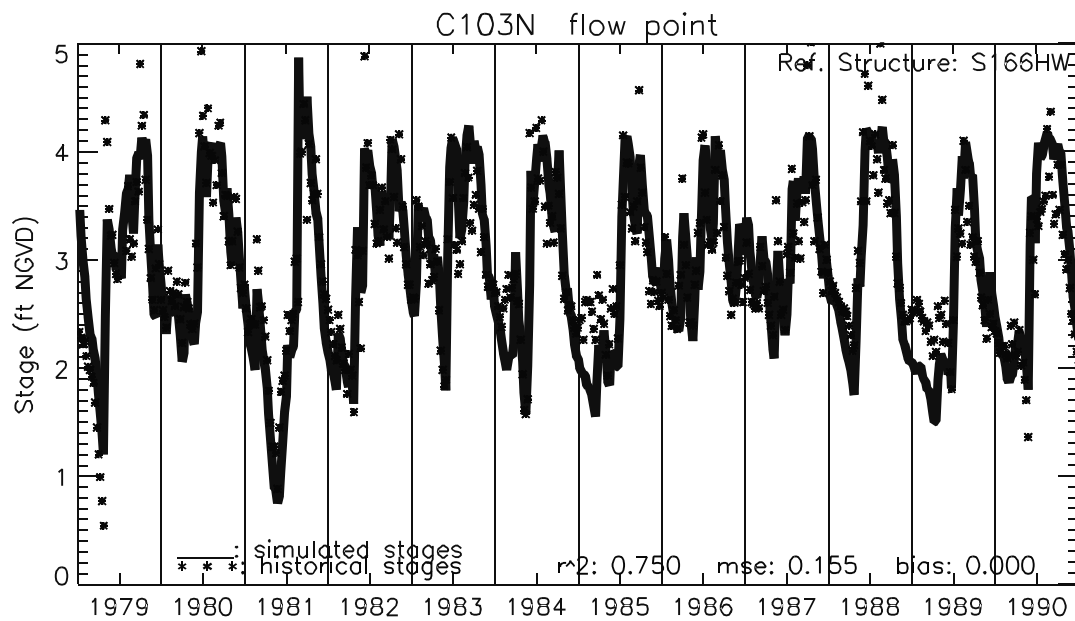


Figure 4.2.7(a) Comparison of Simulated and Historical Mean Weekly Stages along upper C-103N Canal at gaging station S-166HW for Period of Record 1979-1990

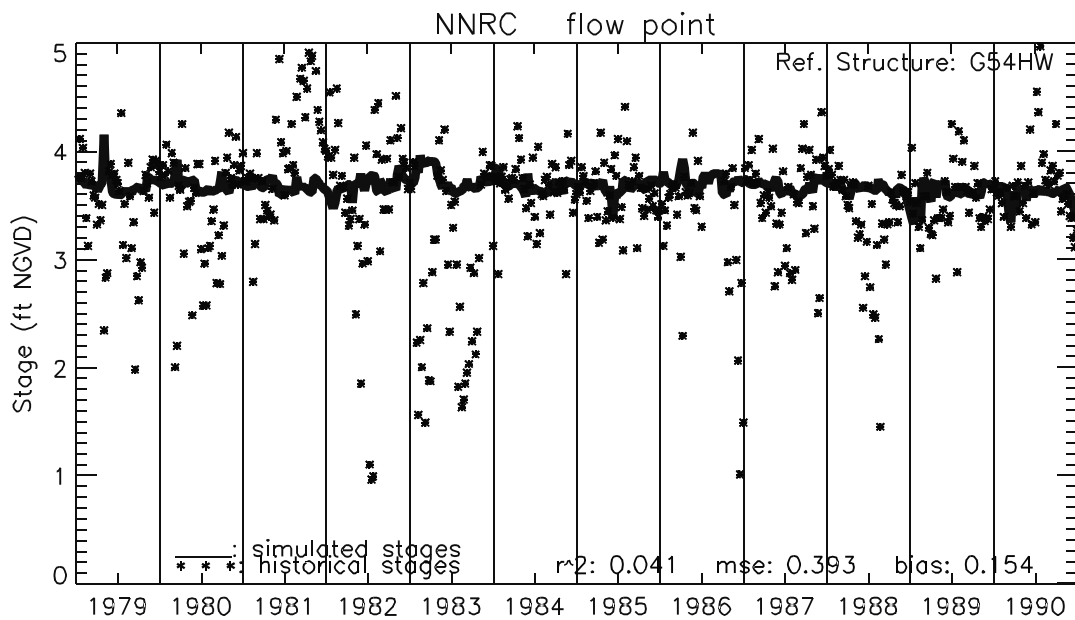


Figure 4.2.7(b) Comparison of Simulated and Historical Mean Weekly Stages along North New River canal at gaging station G-54HW for Period of Record 1979-1990

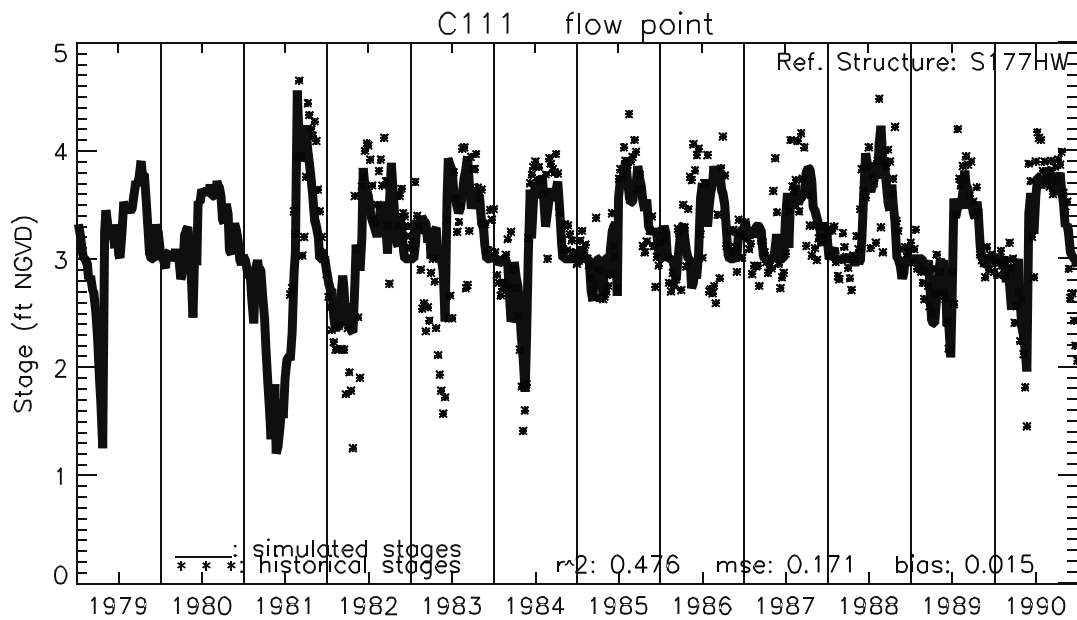


Figure 4.2.8 Comparison of Simulated and Historical Mean Monthly Stages along C-111 Canal at gaging station S-177HW for Period of Record 1979-1990

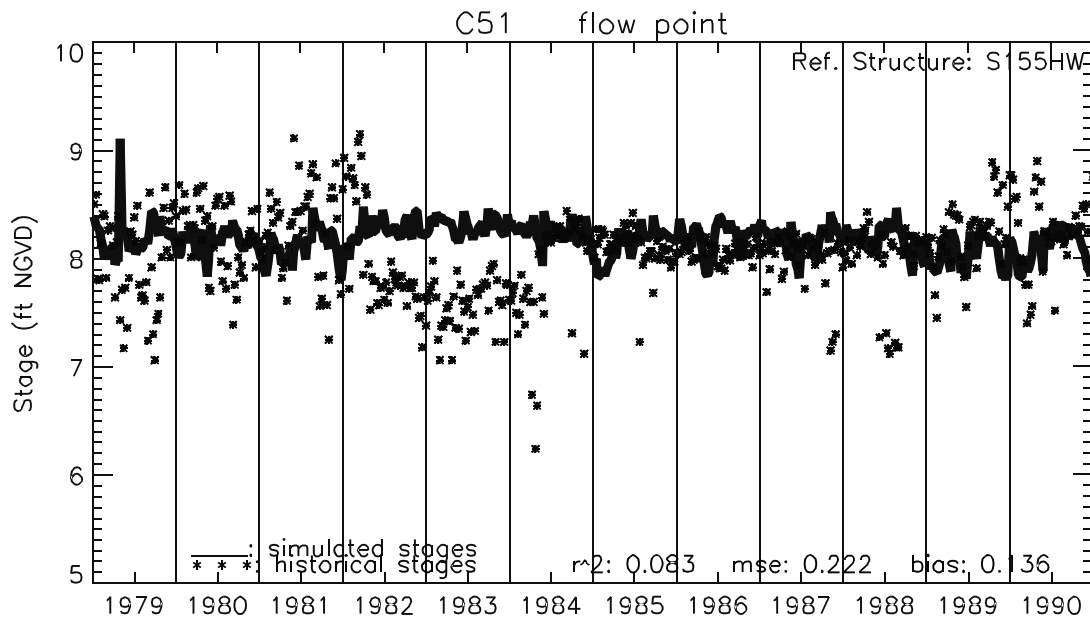
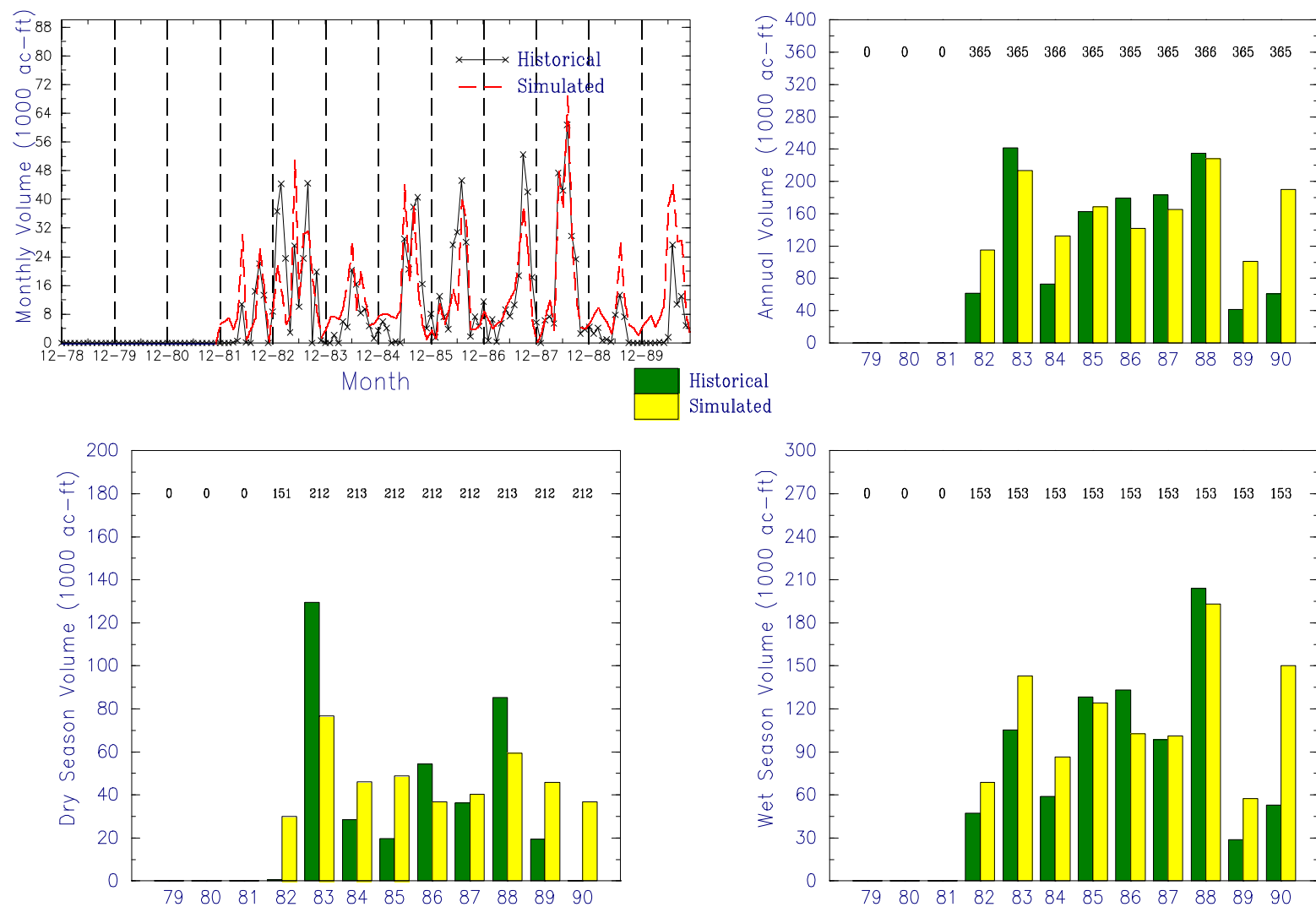


Figure 4.2.9 Comparison of Simulated and Historical Mean Monthly Stages along C-51 Canal at gaging station S-155HW for Period of Record 1979-1990



Note: Simulated data are summed only over those days when corresponding historical data are available.
 Complete historical data should have 365 or 366 days for annual, 212 or 213 days for dry season and 153 days for wet season.
 Values on top of each graph denote the number of days when historical data are available for each category or period.

SFWM v3.5

Figure 4.2.10 Comparison of Simulated and Historical Flows at Structure S-177 for Period of Record 1979-1990

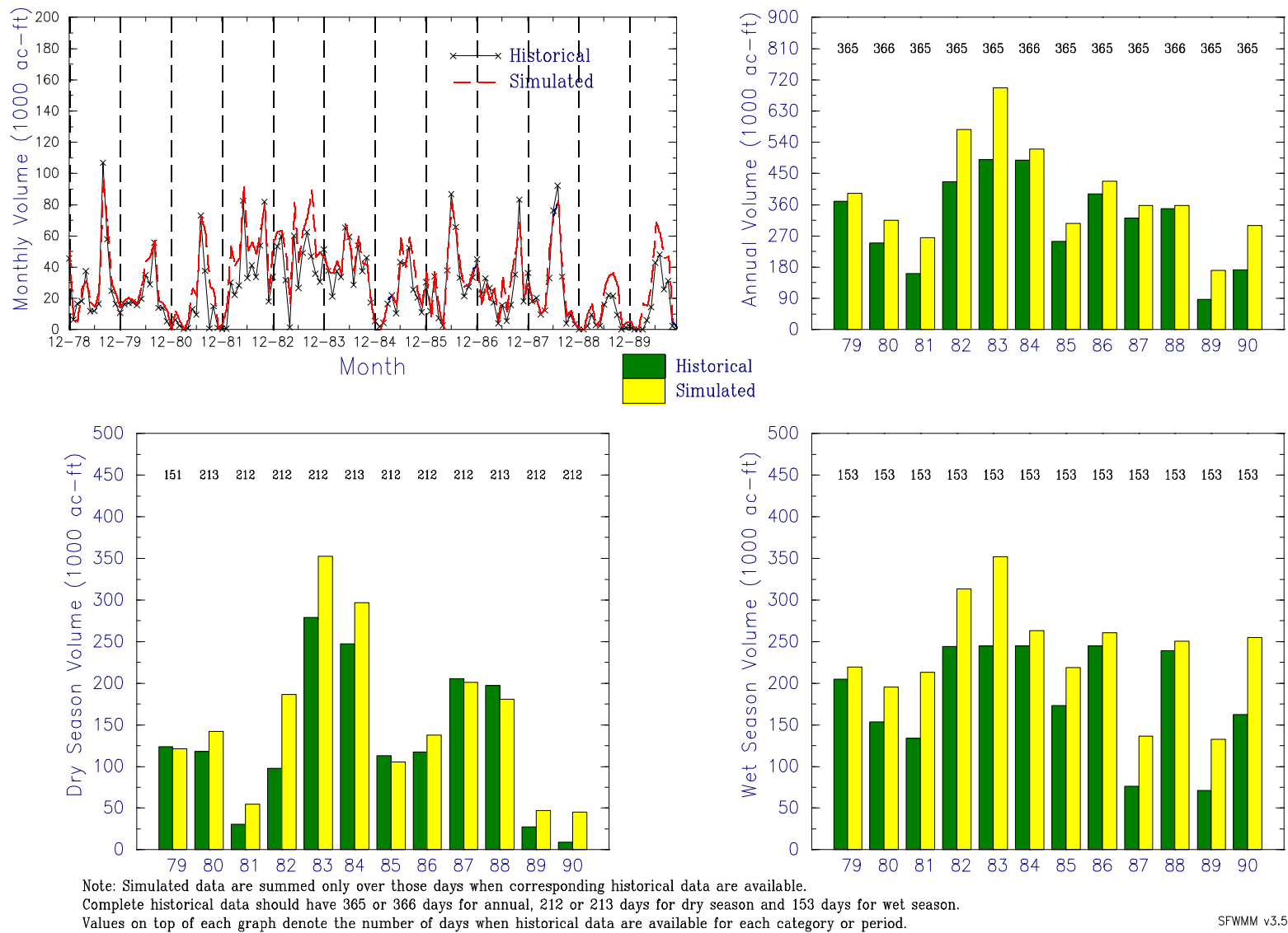


Figure 4.2.11 Comparison of Simulated and Historical Flows at Structure S-155 for Period of Record 1979-1990